# The Routing Table: A Closer Look

**Routing Protocols and Concepts – Chapter 8**

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Version 4.0

# Objectives

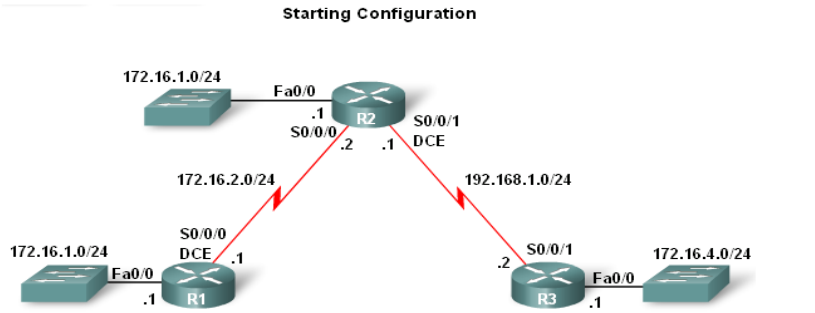
- Describe the various route types found in the routing table structure.
- Describe the routing table lookup process.
- Describe routing behavior in routed networks.

# Introduction

- Chapter focus:
  - Structure of the routing table.
  - Lookup process of the routing table.
  - Classless and classful routing behaviors.

# Routing Table Structure

- Lab topology
- 3 router setup:
  - R1 and R2 share a common 172.16.0.0/16 network with 172.16.0.0/24 subnets
  - R2 and R3 are connected by the 192.168.1.0/24 network
  - R3 also has a 172.16.4.0/24 subnet, which is disconnected, or discontiguous, from the 172.16.0.0 network that R1 and R2 share




```
R1(config)#interface FastEthernet0/0
R1(config-if)#ip address 172.16.1.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#interface Serial0/0/0
R1(config-if)#ip address 172.16.2.1 255.255.255.0
R1(config-if)#clock rate 64000
R1(config-if)#no shutdown
R1(config-if)#end
R1#copy run start
```

```
R3(config)#interface FastEthernet0/0
R3(config-if)#ip address 172.16.4.1 255.255.255.0
R3(config-if)#no shutdown
R3(config-if)#interface Serial0/0/1
R3(config-if)#ip address 192.168.1.2 255.255.255.0
R3(config-if)#clock rate 64000
R3(config-if)#no shutdown
R3(config-if)#end
R3#copy run start
```

# Routing Table Structure

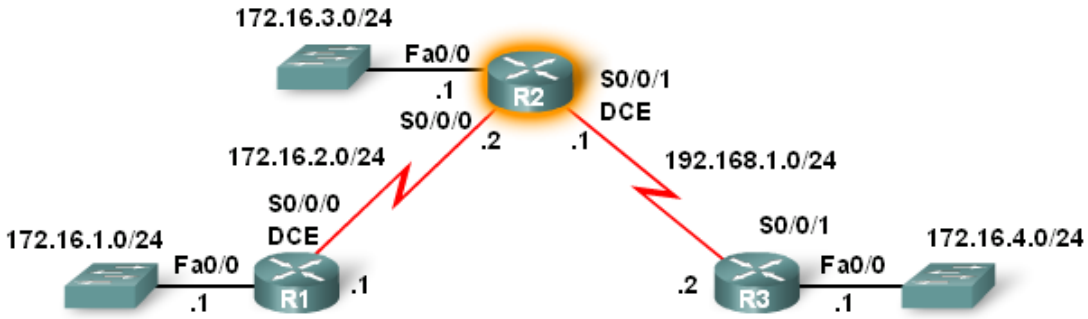
- Routing table entries come from the following sources:
  - Directly connected networks
  - Static routes
  - Dynamic routing protocols

**Sample Routing Table**

```
Router#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile,
<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 4 subnets
S       172.16.4.0 is directly connected, Serial0/0/1
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:08, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
     10.0.0.0/16 is subnetted, 1 subnets
S       10.1.0.0 is directly connected, Serial0/0/1
C    192.168.1.0/24 is directly connected, Serial0/0/1
S    192.168.100.0/24 is directly connected, Serial0/0/1
Router#
```

# Routing Table Structure

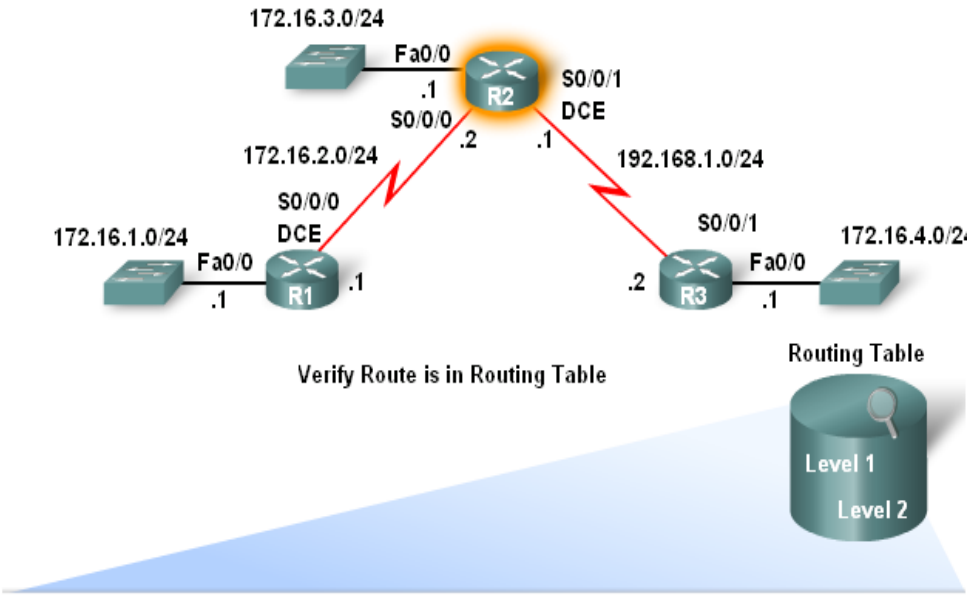
- Level 1 routes
- As soon as the no shutdown command is issued the route is added to routing table




```
R2#debug ip routing
IP routing debugging is on
R2#conf t
R2(config)#interface serial 0/0/1
R2(config-if)#ip address 192.168.1.1 255.255.255.0
R2(config-if)#clock rate 64000
R2(config-if)#no shutdown
R2(config-if)#
00:11:06: %LINK-3-UPDOWN: Interface Serial0/0/1, changed state to up
R2(config-if)#
RT: add 192.168.1.0/24 via 0.0.0.0, connected metric [0/0]
RT: interface Serial 0/0/1 added to routing table
R2(config-if)#end
R2#undebug all
All possible debugging has been turned off
```

# Routing Table Structure

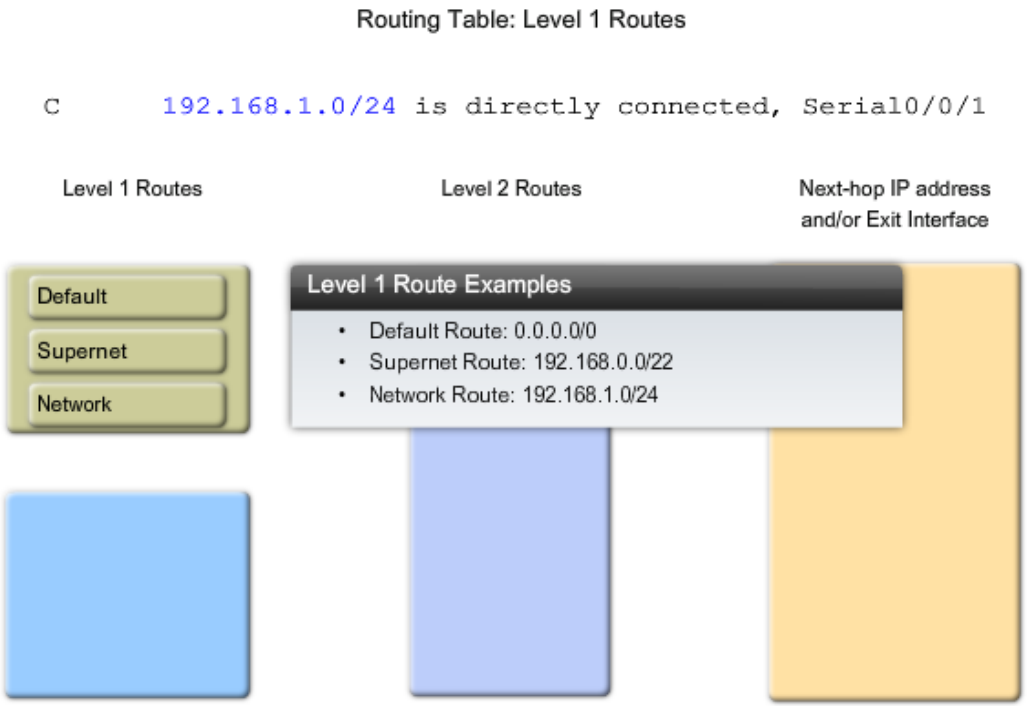
- Cisco IP routing table is a hierarchical structure
- The reason for this is to speed up lookup process




```
R2#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.1.0/24 is directly connected, Serial0/0/1
```

# Routing Table Structure

- Level 1 routes:
  - Have a subnet mask equal to or less than the classful mask of the network address
- Level 1 routes can function as:
  - Default routes
  - Supernet routes
  - Network routes



# Routing Table Structure

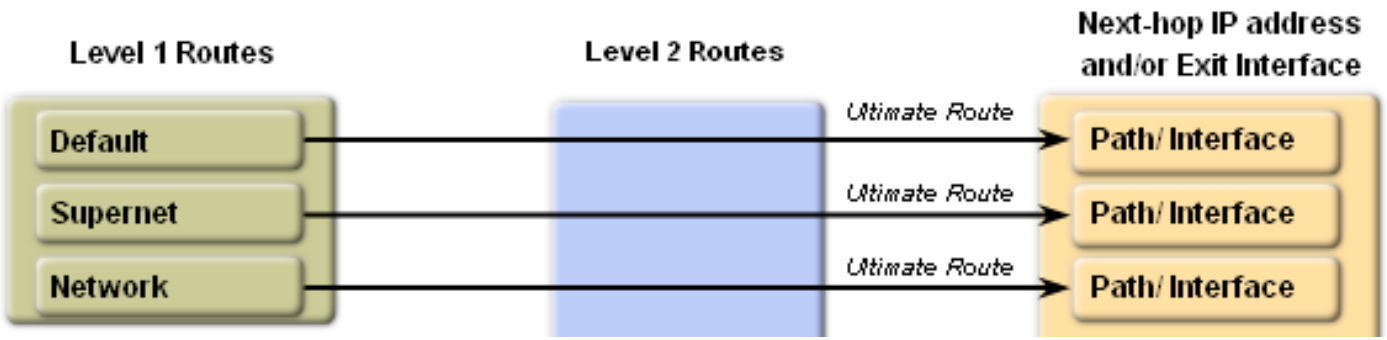
- Level 1 routes:
  - Ultimate routes includes either:
    - A next-hop address

      **OR**

    - An exit interface

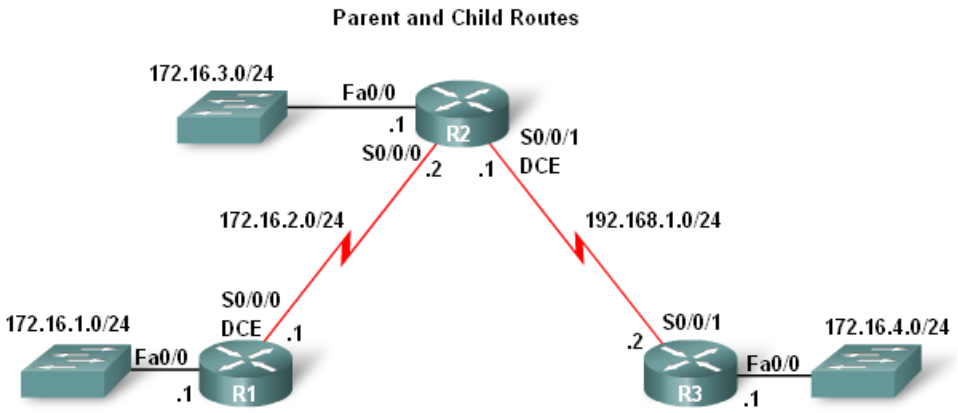
**Routing Table: Level 1 Routes**

```
C       192.168.1.0/24 is directly connected, Serial0/0/1
```



# Routing Table Structure

- Parent and child routes:
  - A **parent route** is a level 1 route
  - A **parent route does not contain** any next-hop IP address **or** exit interface information

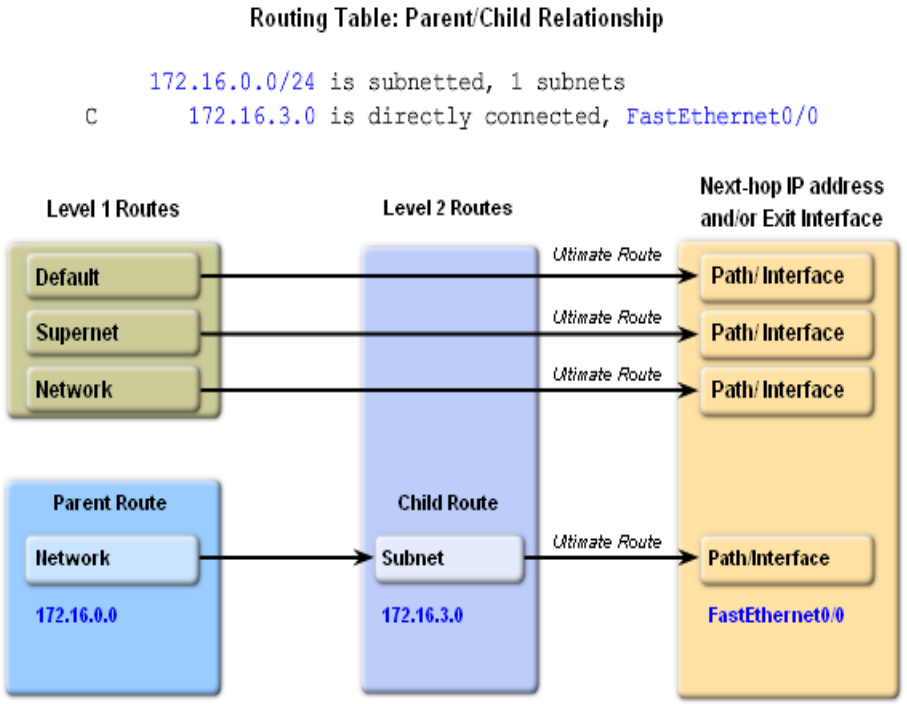



Parent and Child Routes

```
R2(config)#interface fastethernet 0/0
R2(config-if)#ip address 172.16.3.1 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#end
R2#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile,
<text omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 1 subnets   Level 1 Parent Route
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
R2#
```

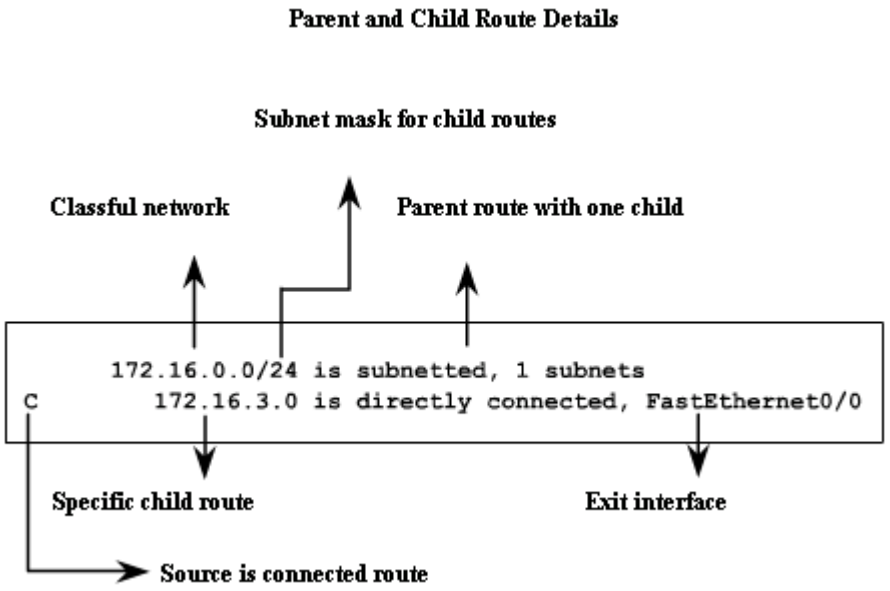
# Routing Table Structure

- Automatic creation of parent routes:
  - Occurs any time a subnet is added to the routing table
- Child routes:
  - Child routes are **level 2** routes
  - Child routes are a **subnet** of a classful network address



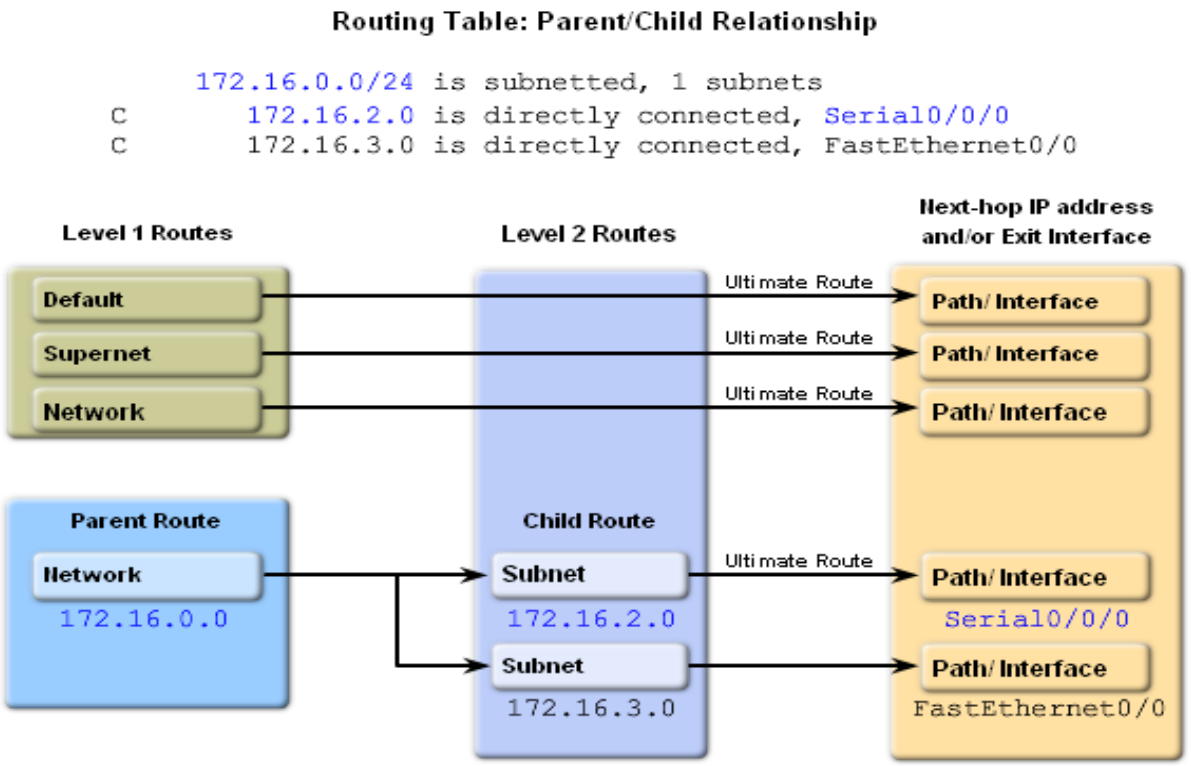
# Routing Table Structure

- Level 2 child routes contain route source and the network address of the route
- Level 2 **child routes are** also considered **ultimate routes**
  - *Reason:* they contain the next hop address and/or exit interface



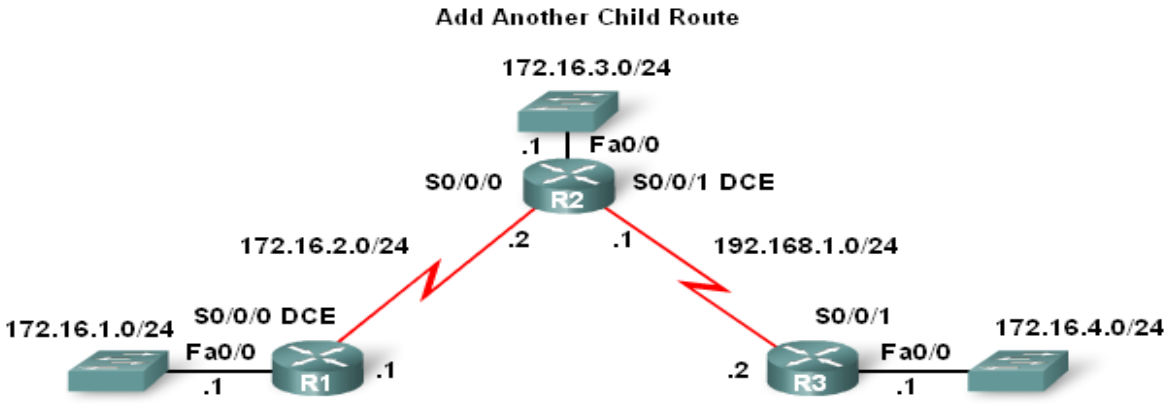
# Routing Table Structure

- Both child routes have the same subnet mask. This means the parent route maintains the /24 mask



# Routing Table Structure

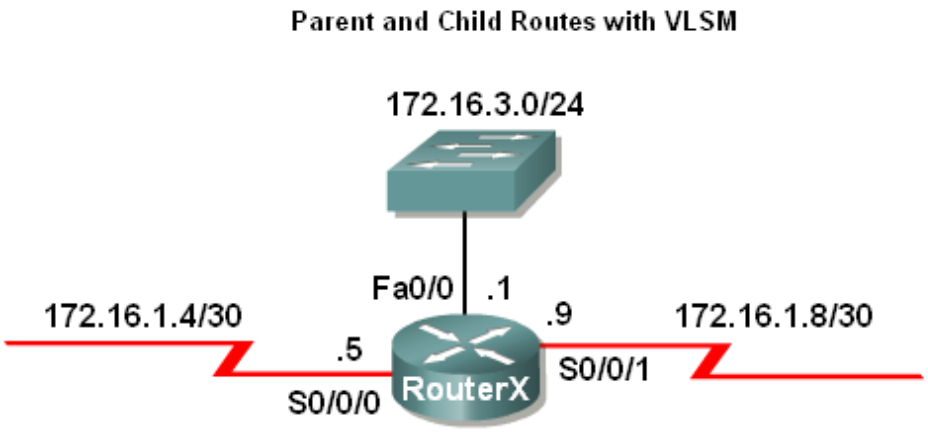
- Diagram illustrates 2 child networks belonging to the parent route 172.16.0.0 / 24:




```
R2(config)#interface serial 0/0/0
R2(config-if)#ip address 172.16.2.2 255.255.255.0
R2(config-if)#no shutdown
R2(config-if)#end
R2#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile,
<text omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 1 subnets        Level 1 Parent Route
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
R2#
```

# Routing Table Structure

- In classless networks, child routes do not have to share the same subnet mask.




Parent and Child Routes with VLSM

```
RouterX#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
<output omitted>

Gateway of last resort is not set

     172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks
C       172.16.1.4/30 is directly connected, Serial0/0/0
C       172.16.1.8/30 is directly connected, Serial0/0/1
C       172.16.3.0/24 is directly connected, FastEthernet0/0
RouterX#
```

Level 1 Parent Route

Level 2 Child Route

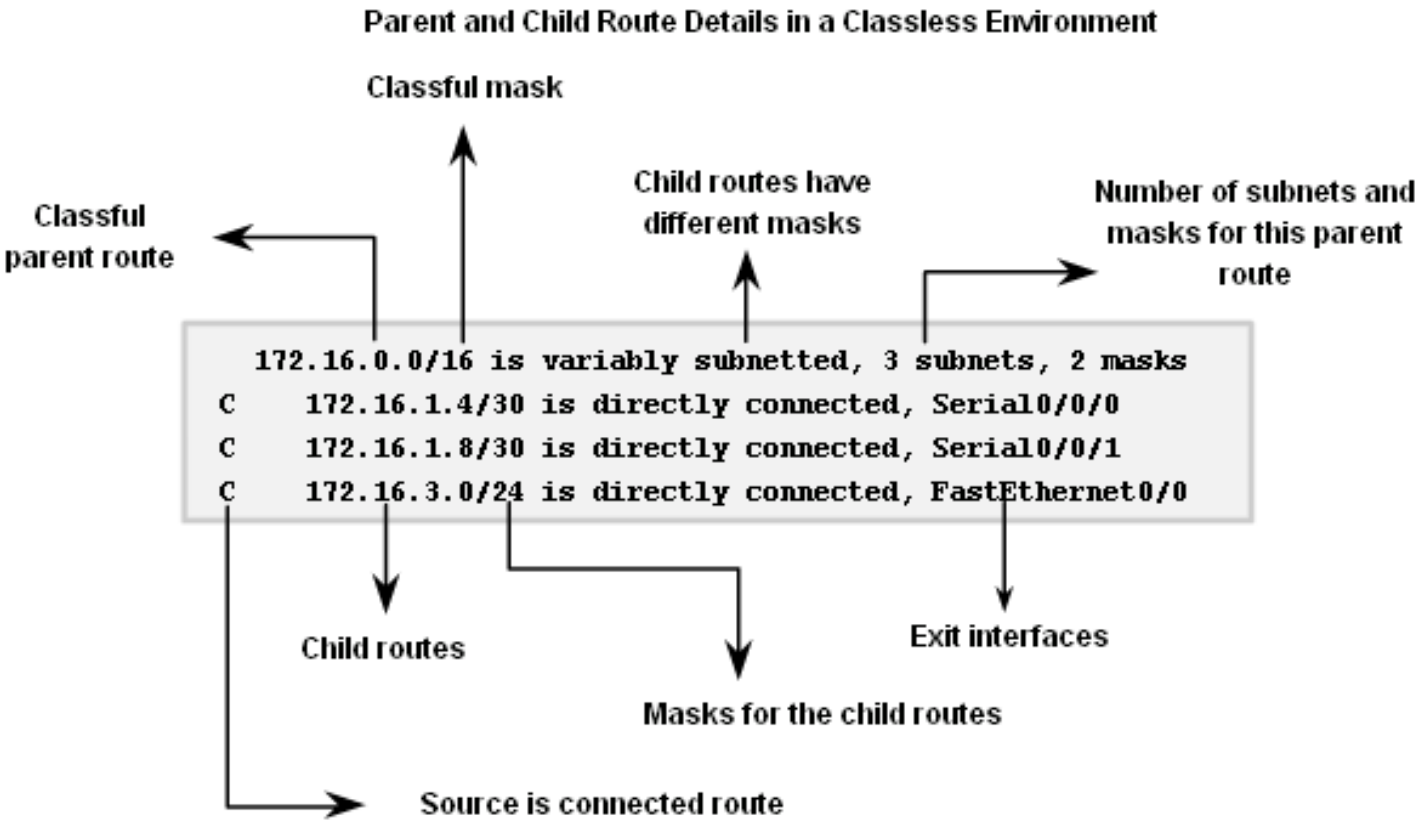
# Routing Table Structure

- Parent & Child Routes: Classless Networks

| Network type | Parent route's classful mask is displayed | Term variably subnetted is seen in parent route in routing table | Includes the # of different masks of child routes | Subnet mask included with each child route entry |
|---|---|---|---|---|
| **Class-ful** | No | No | No | No |
| **Class-less** | Yes | Yes | Yes | Yes |

# Routing Table Structure

- Parent & Child Routes: Classless Networks



# Routing Table Lookup Process

- The Route Lookup Process
  - **Examine level 1 routes:**
    - If best match a level 1 ultimate route and is not a parent route this route is used to forward packet
  - **Router examines level 2 (child) routes:**
    - If there is a match with level 2 child route then that subnet is used to forward packet
    - If no match then determine routing behavior type
  - **Router determines classful or classless routing behavior:**
    - If classful then packet is dropped
    - If classless then router searches level one supernet and default routes
    - If there exists a level 1 supernet or default route match then Packet is forwarded, if not packet is dropped

# Routing Table Lookup Process

- Longest Match: Level 1 Network Routes:
  - Best match is also known as the longest match
  - The **best match** is the one that has the most number of left most bits matching between the destination IP address and the route in the routing table

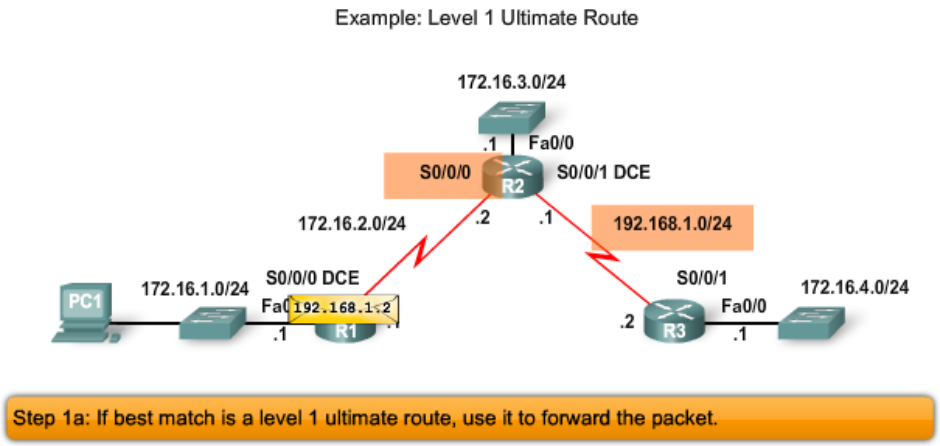
**Longest Match is the Preferred Route**

| | | |
|---|---|---|
| IP Packet Destination | 172.16.0.10 | 10101100.00010000.00000000.00001010 |
| Route 1 | 172.16.0.0/12 | 10101100.00010000.00000000.00000000 |
| Route 2 | 172.16.0.0/18 | 10101100.00010000.00000000.00000000 |
| Route 3 | 172.16.0.0/26 | 10101100.00010000.00000000.00000000 |

Longest Match to IP Packet Destination

# Routing Table Lookup Process

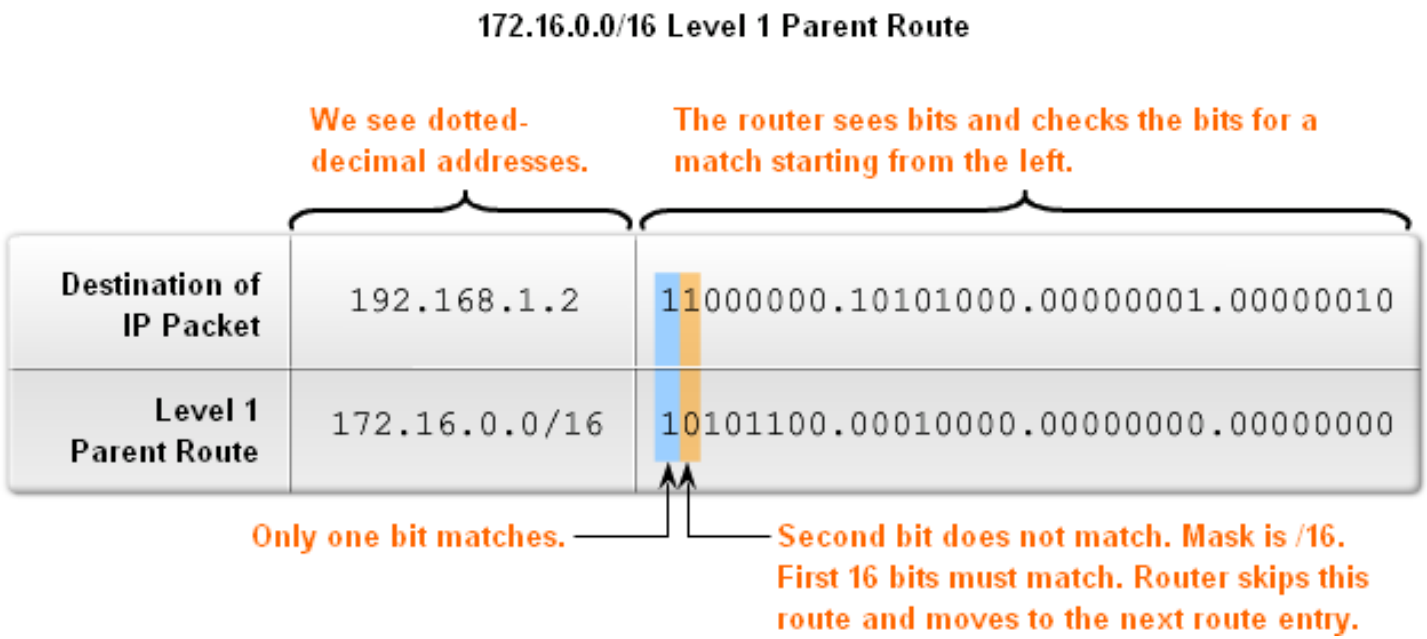
- Finding the subnet mask used to determine the longest match
- **Scenario:**
  - PC1 pings 192.168.1.2
  - Router examines level 1 route for best match
  - There exist a match between 192.168.1.2 and 192.168.1.0 / 24
  - Router forwards packets out s0/0/0




```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B -
BGP
       (**output omitted**)

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

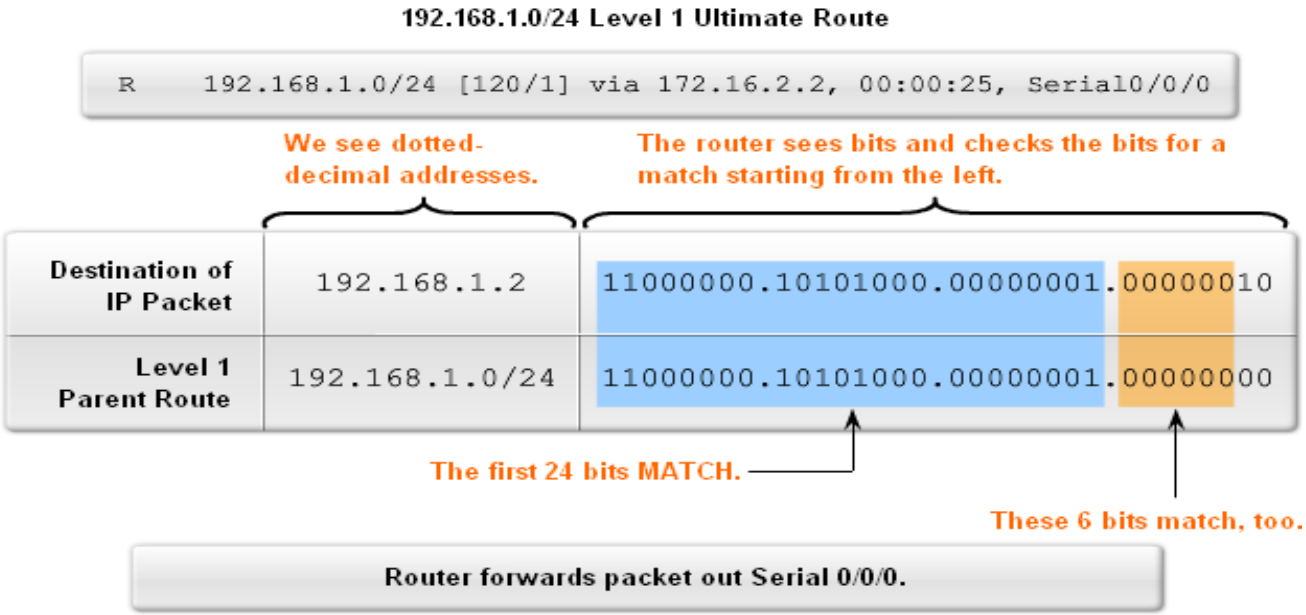
# Routing Table Lookup Process

- The process of matching:
  - 1st there must be a match made between the parent route & destination IP
  - If a match is made then an attempt at finding a match between the destination IP and the child route is made



# Routing Table Lookup Process

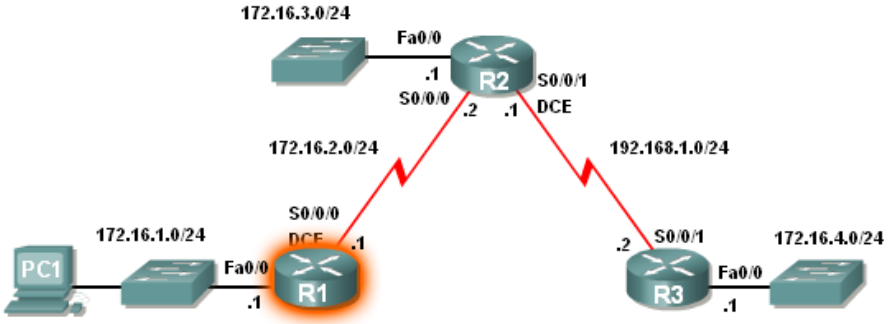
- Finding a match between the packet's destination IP address and the next route in the routing table:
  - The figure shows a match between the destination IP of 192.168.1.2 and the level one IP of 192.168.1.0 / 24 then packet forwarded out s0/0/0



# Routing Table Lookup Process

- Level 1 Parent & Level 2 Child Routes
- Before level 2 child routes are examined
  - There must be a match between classful level one parent route and destination IP address

**Example: Level 1 Parent Route and Level 2 Child Routes**

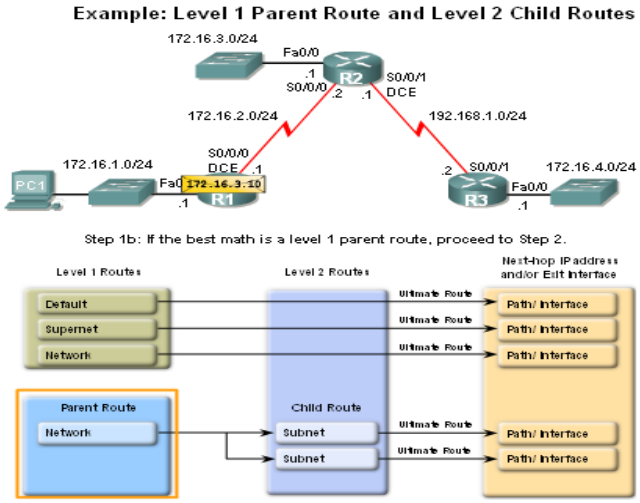


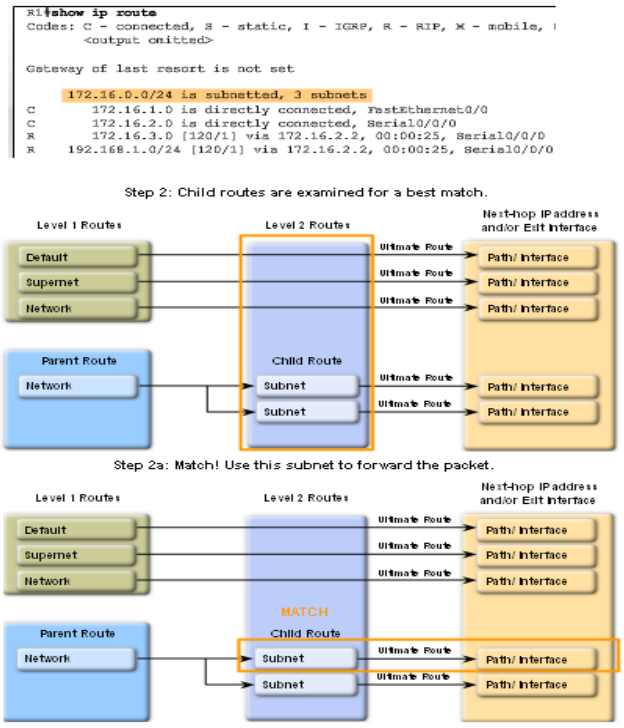

```
R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B -
BGP
       <output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.1.0 is directly connected, FastEthernet0/0
C       172.16.2.0 is directly connected, Serial0/0/0
R       172.16.3.0 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
R    192.168.1.0/24 [120/1] via 172.16.2.2, 00:00:25, Serial0/0/0
```

Level 1 Parent Route "Header" for Child Routes

# Routing Table Lookup Process

- After the match with parent route has been made Level 2 child routes will be examined for a match
  - Route lookup process searches for child routes with a match with destination IP



# Routing Table Lookup Process

- How a router finds a match with one of the level 2 child routes:
  - First router examines parent routes for a match. If a match exists then:
    - Child routes are examined
    - Child route chosen is the one with the longest match

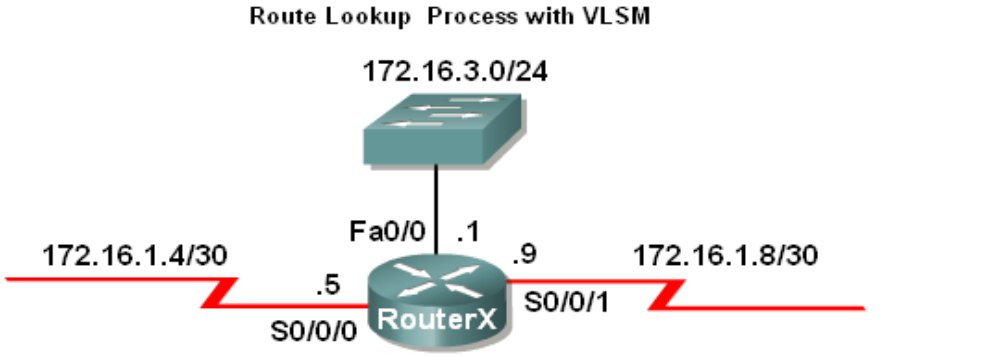
**Example: Level 1 Parent Route and Level 2 Child Routes**

| | | |
|---|---|---|
| Destination of IP Packet | 172.16.3.10 | 10101100 00010000 00000011 00001010 |
| Level 1 Parent Route | 172.16.0.0/16 | 10101100 00010000 00000000 00000000 |
| Level 2 Child Route | 172.16.1.0/24 | 10101100 00010000 00000001 00000000 |
| Level 2 Child Route | 172.16.2.0/24 | 10101100 00010000 00000010 00000000 |
| Level 2 Child Route | 172.16.3.0/24 | 10101100 00010000 00000011 00000000 |

First 24 bits match.

# Routing Table Lookup Process

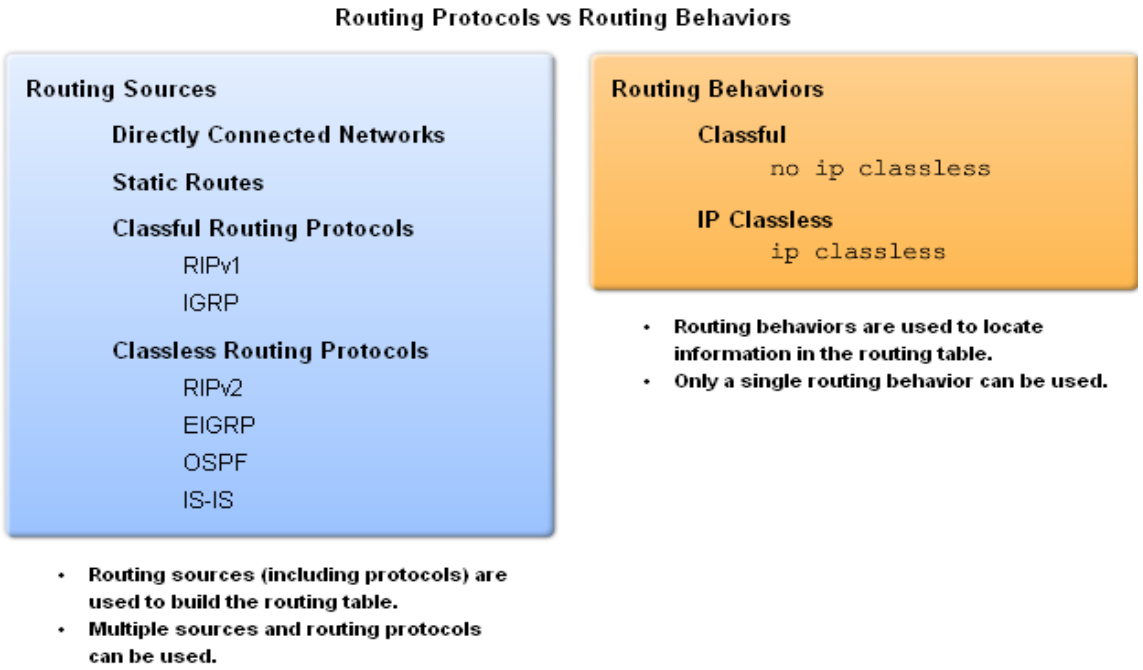
- Example – Route Lookup Process with VLSM:
  - The use of VLSM does not change the lookup process
  - If there is a match between destination IP address and the level 1 parent route then Level 2 child routes will be searched




```
RouterX#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
<output omitted>

Gateway of last resort is not set

     172.16.0.0/16 is variably subnetted, 3 subnets, 2 masks   Level 1 Parent Route
C       172.16.1.4/30 is directly connected, Serial0/0/0
C       172.16.1.8/30 is directly connected, Serial0/0/1
C       172.16.3.0/24 is directly connected, FastEthernet0/0
RouterX#
```

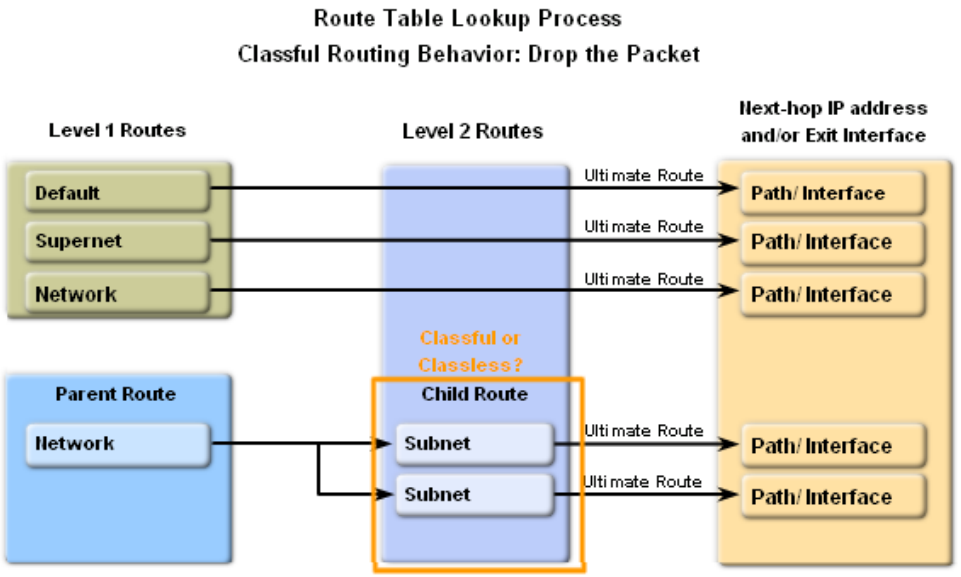
# Routing Behavior

- Classful & classless **routing protocols:**
  - Influence how routing table is **populated**
- Classful & classless **routing behaviors:**
  - Determines how routing table is **searched** after it is filled



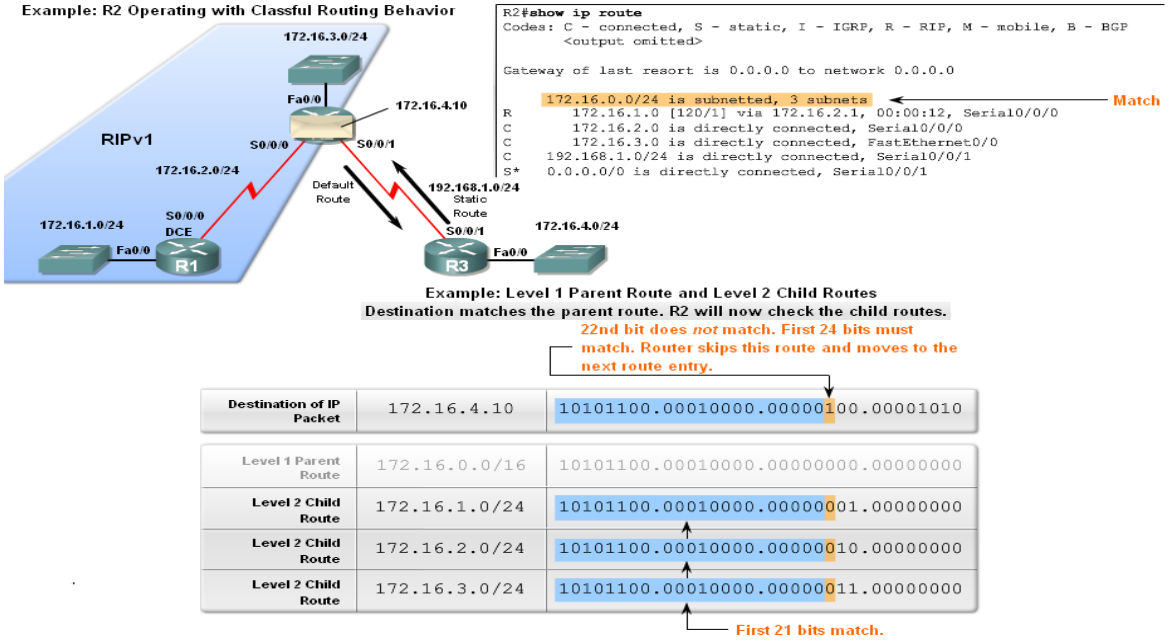
# Routing Behavior

- Classful Routing Behavior: no ip classless
- What happens if there is not a match with any level 2 child routes of the parent?
  - Router must determine if the routing behavior is classless or classful
  - If router is utilizing **classful routing behavior** then lookup process is terminated and **packet is dropped**



# Routing Behavior

- Classful Routing Behavior – Search Process
- An example of when classful routing behavior is in effect and why the router drops the Packet
  - The destination's subnet mask is a /24 and none of the child routes left most bits match the first 24 bits. This means packet is dropped.



# Routing Behavior

- Classful Routing Behavior – Search Process
- The reason why the router will not search beyond the child routes:
  - Originally networks were all classful
  - This meant an organization could subnet a major network address and “enlighten” all the organization’s routers about the subnetting
  - Therefore, if the subnet was not in the routing table, the subnet did not exist and packet was dropped

# Routing Behavior

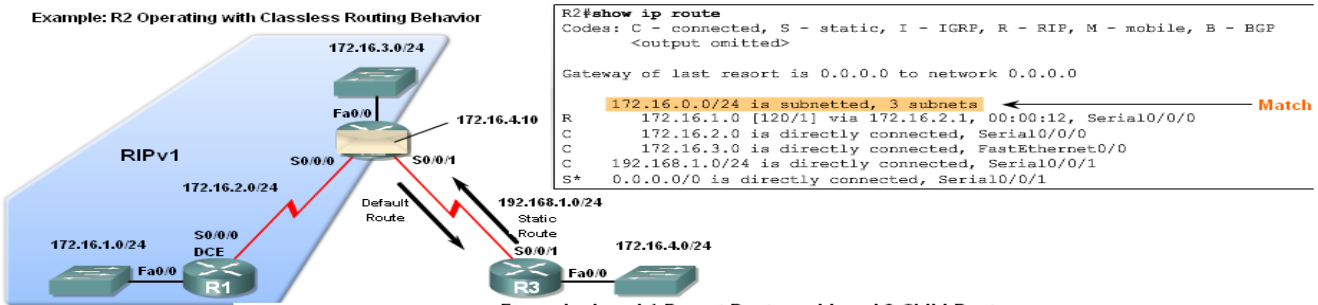
- Classless Routing Behavior: ip classless
- Beginning with IOS 11.3, ip classless was configured by default
- Classless routing behavior works for:
  - Discontiguous networks
    and
  - CIDR supernets

# Routing Behavior

- Classless Routing Behavior: ip classless
- Route lookup process when ip classless is in use:
  - If **classless routing behavior** in effect then:
    - Search level 1 routes
    - Supernet routes checked first
  - If a match exists then forward packet
    - Default routes checked second
  - If there is no match or no default route then the packet is dropped

# Routing Behavior

- Classless Routing Behavior – Search Process
- Router begins search process by finding a match between destination IP and parent route
  - After finding the above mentioned match, then there is a search of the child route




**Example: Level 1 Parent Route and Level 2 Child Routes**
**Destination matches the parent route. R2 will now check the child routes.**

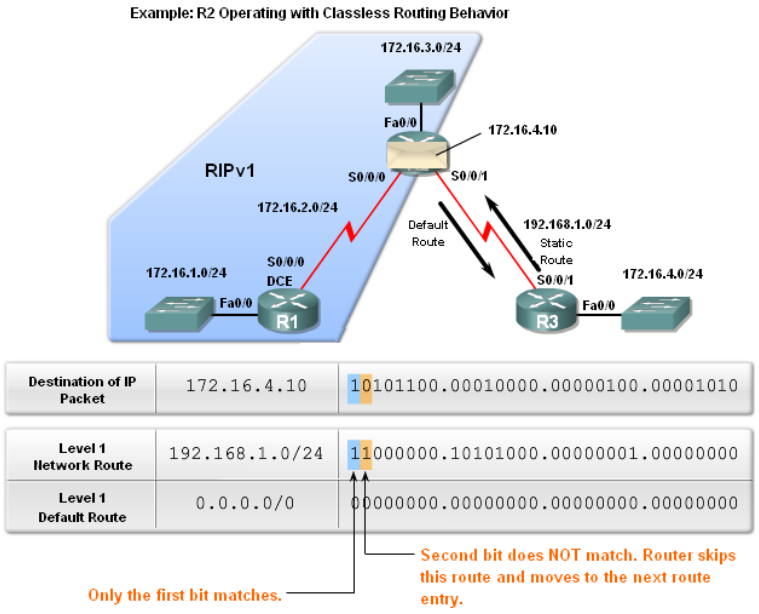
22nd bit does *not* match. First 24 bits must match. Router skips this route and moves to the next route entry.

| | | |
|---|---|---|
| Destination of IP Packet | 172.16.4.10 | 10101100.00010000.00000100.00001010 |
| Level 1 Parent Route | 172.16.0.0/16 | 10101100.00010000.00000000.00000000 |
| Level 2 Child Route | 172.16.1.0/24 | 10101100.00010000.00000001.00000000 |
| Level 2 Child Route | 172.16.2.0/24 | 10101100.00010000.00000010.00000000 |
| Level 2 Child Route | 172.16.3.0/24 | 10101100.00010000.00000011.00000000 |

First 21 bits match.

# Routing Behavior

- Classless Routing Behavior – Search Process
- If no match is found in child routes of previous slide then:
  - Router continues to search the routing table for a match that may have fewer bits in the match




A /0 mask means that no bits have to match to use the default route. R2 uses the default route and forwards the packet.

| Destination of IP Packet | 172.16.4.10 | 10101100.00010000.00000100.00001010 |
|---|---|---|
| Level 1 Network Route | 192.168.1.0/24 | 11000000.10101000.00000001.00000000 |
| Level 1 Default Route | 0.0.0.0/0 | 00000000.00000000.00000000.00000000 |

```
R2#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile,
       <output omitted>

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

     172.16.0.0/24 is subnetted, 3 subnets
R       172.16.1.0 [120/1] via 172.16.2.1, 00:00:12, Serial0/0/0
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
S*   0.0.0.0/0 is directly connected, Serial0/0/1
```

Match
No Match
No Match
No Match
No Match
Use Default

The default route IS used. R2 forwards packet to R3.

# Routing Behavior

- **Classful** vs. **Classless Routing Behavior**:
  - It is recommended to use classless routing behavior
    - *Reason*: so supernet and default routes can be used whenever needed

# Summary

- Content / structure of a routing table:
- Routing table entries:
  - Directly connected networks
  - Static route
  - Dynamic routing protocols
- Routing tables are hierarchical:
  - Level 1 route:
    - Have a subnet mask that is less than or equal to classful subnet mask for the network address.
  - Level 2 route:
    - These are subnets of a network address.

# Summary

- Routing table lookup process:
  - **Level 1 route examination:**
    - Begins with examining level 1 routes for best match with packet's destination IP. If the best match equals an ultimate route then packet is forwarded, or else…
    - Parent route is examined. If parent route & destination IP match then Level 2 (child) routes are examined.
  - **Level 2 route examination:**
    - If a match between destination IP and child route found then packet forwarded, or else…
    - If Router is using classful routing behavior then packet is dropped, or else…
    - If router is using classless routing behavior then router searches Level 1 supernet and default routes for a match. If a match is found then Packet is forwarded, or else…
    - Packet is dropped.

# Summary

- Routing behaviors:
  - This refers to how a routing table is searched.
- Classful routing behavior:
  - Indicated by the use of the no ip classless command.
  - Router will not look beyond child routes for a lesser match.
- Classless routing behavior:
  - Indicated by the use of the ip classless command.
  - Router will look beyond child routes for a lesser match.